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(54) MAGNETIC FIELD DRIVE

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MAGNETIC FIELD DRIVE

BACKGROUND OF THE INVENTION

This invention relates to novel means for producing electromagnetic fields of unprecedented magnitude and intensity.

This invention further relates to magnetic field propulsion means operable to lift a vehicle from the surface of the earth.

The present invention also relates to novel means for converting fusion energy to magnetic field energy.

This invention further relates to novel means operable to emit ions.

Present day electromagnets are capable of producing fields which are very weak in relation to the weight of the electromagnet. This limitation stems from the necessity for conducting metal wires which serve to carry the electric charges (i.e. conduction electrons) which, by their motion, induce a magnetic field. However, in any volume of conducting metal, the member of free conduction electrons present is limited by maximum densities characteristic of each metal. Furthermore, the total weight of the electrons which participate in the conduction process forms an extremely small fraction of the total weight of the metal which surrounds them. In order to produce more intense electromagnetic fields, it has heretofore been necessary to increase the number of conducting coils and hence the weight of the electromagnet.

Moreover, the motion of the conduction electrons is restrained by the resistivity of the metal in which they move. It is well known that resistivity in metals is primarily due to the thermal agitation of the atoms and conduction electrons of the metal. It is further known that such resistivity may be effectively eliminated by maintaining the temperature of the conducting metal at or below the liquefaction temperature of hydrogen. The metal is then said to be in superconducting state. Such low temperatures necessitate the use of complex (and massive) refrigeration and insulation installations.

("Intense Magnetic Fields" Henry H. Kolm and Arthur J. Freeman - Scientific American, p. 66 - 78, April, 1965).

The above-mentioned Scientific American reference discloses a three ton electromagnet which provides a field of 250,000 oersteds in a centrally located cylindrical cavity which is only a few inches in diameter. This small cavity is then used for experiments relating to the effects of intense electromagnetic fields. It is evident that a much larger volume permeated by intense electromagnetic fields would be greatly appreciated by the experimentor.

It may therefore be said that while high magnetic field energy densities (i.e. intense magnectic field throughout small volumes) are presently available, high magnetic field energies (i.e. intense magnetic fields throughout large volumes) per se cannot be attained by present day means.

Moreover, present day electromagnets are powered by relatively expensive electric energy produced in hydroelectric and atomic (fission) reactor installations.

The massiveness of such sources of electric energy together with the above-outlined limitations on present day electromagnets precludes the utilization of electromagnetic field interaction to propel a vehicle from the surface of the earth in a manner which will hereinafter be disclosed.

Present day means for atmospheric and/or space travel are both expensive and inefficient. These disadvantages are typified by the chemical fuel rockets which are now being used to place satellites in orbit about the earth.

Such rockets operate somewhat in the manner of projectiles. Their proper functioning is entirely dependent upon the cooperation of tens of thousands of components needed for guidance and control. Furthermore, a chemical fuel rocket capable of placing a one ton projectile in orbit about the earth is typically hundreds of feet in length, weighs hundreds of tons, and costs tens of millions

of dollars to construct; this costly product of engineering ingenuity is then discarded after a single usage. It is apparent that an alternative to such waste would be highly desirable.

The present invention provides a magnetic propulsion method and apparatus for producing and maintaining sufficient magnetic field energy to impart mobility to an object by interaction with a second magnetic field, such as the geomagnetic field of the earth.

Moreover, the present invention provides means for producing magnetic field energies of unprecedented magnitude.

The present invention further provides a method and apparatus for converting thermonuclear fusion energy into magnetic field energy.

The present invention also provides an efficient, reusable vehicle which is operable for atmospheric and space travel.

The present invention further provides an apparatus capable of emitting a directed, high velocity stream of ions.

TERMS OF REFERENCE

In the context of the present invention, and to facilitate a clear understanding thereof, the following definitions should be particularly noted:

ions - electrons, protons, electrostatically charged atoms, electrostatically charged molecules, or any combination thereof;

charged gas - a gas having an overall electrostatic charge. Such a charged gas should preferably be composed solely of ions of one electrical charge or polarity; however, the charged gas may include a predominant amount of ions of one polarity (e.g. positive), a smaller proportion of ions of the other polarity (e.g. negative), and may optionally also include some neutral particles (e.g. neutral atoms or molecules);

ionized gas - a gas wherein at least some of the gas molecules have been converted into ions by the loss of at least one electron;

plasma - an ionized gas at temperatures in excess of $10^6$ $^oC$ and wherein the majority of the gas molecules have been converted into ions;

fusion plasma - a plasma whose temperature is sufficiently high (e.g. $10^8$ $^oC$) to kindle a thermonuclear fusion reaction. The fusion plasma of this definition is a plasma in which a fusion reaction is occurring or can occur;

fusion energy - the energy released by a fusion reaction (e.g. ${}_1H^2 + {}_1H^2 \rightarrow {}_2He^3 + {}_0n^1 + E$). This energy generally takes the form of heat energy and raises the kinetic temperature of a plasma within which the fusion reaction occurs;

endless tubular enclosure - an enclosure having the form of a hollow tube with its ends joined together and having walls of material composition. While a hollow, toroidal configuration is preferred, any other endless configuration (e.g. helical with the ends joined) may be employed;

circulation velocity - the velocity of ions in their circuital motion along the endless hollow containment volume defined by the above-defined endless, tubular enclosure. With illustrative reference to a hollow torus, the circuital motion would be a predominantly circular, unidirectional circumferential motion about the axis of the torus and within the hollow toroidal containment volume;

magnetic enclosure ("magnetic bottle") - an enclosure wherein containment of ions is achieved by the action of static and/or dynamic magnetic fields;

energizing a magnetic enclosure - supplying electric energy to the field generators which produce the magnetic fields that define the magnetic enclosure;

ionomagnet - an apparatus for producing a magnetic field by the circulation of a charged gas about and within a hollow, endless enclosure;

SUMMARY OF THE INVENTION

Various broad embodiments of the present invention will now be disclosed.

Ionomagnet Embodiments

AI

Method:

The present invention provides a novel method for producing a magnetic field, characterized by the successive steps of:

(a) enclosing a charged gas within an endless, tubular enclosure, said charged gas having an overall electrostatic charge:

(b) circulating at least some of the enclosed charged gas at circulation velocities in excess of 0.001 c.

Apparatus:

The present invention provides an apparatus for producing a magnetic field, said apparatus comprising in combination:

(a) an endless tubular enclosure;

(b) a charged gas enclosed within the endless tubular enclosure, said charged gas having an overall electrostatic charge;

(c) circulation means operable to circulate at least some of said charged gas around said endless, tubular enclosure at circulation velocities in excess of 0.001 c.

AII

Method:

The present invention provides a novel method for producing a magnetic field, characterized by the successive steps of:

(a) generating and confining a plasma within an endless, tubular magnetic enclosure;

(b) depleting said plasma of at least some plasma ions of one polarity while maintaining said plasma to thereby leave a charged plasma having an overall electrostatic charge within the

enclosure; then

(c) lowering the temperature of said plasma below a pre-selected temperature characteristic of the material composition of the enclosure; then

(d) circulating at least some of the enclosed charged plasma around said endless, tubular, magnetic enclosure.

AII

Apparatus:

The present invention provides an apparatus for producing a magnetic field, said apparatus comprising in combination:

(a) an endless, tubular, magnetic enclosure energizable by electric energy;

(b) a plasma enclosed within the magnetic enclosure, said plasma having an overall electrostatic charge;

(c) charge control means operable to adjust the overall electrostatic charge of said plasma;

(d) circulation means operable to circulate at least some of said plasma around the endless, magnetic enclosure at circulation velocities in excess of 0.001 c, said circulation means being energizable by electric energy.

Magnetic Field Energy Converter Embodiments

BI-i

The present invention provides a device for generating magnetic field energy, said device comprising in combination:

(a) an endless, tubular enclosure;

(b) a charged gas enclosed within the endless, tubular enclosure, said charged gas having an overall electrostatic charge;

(c) circulation means operable to circulate at least some of said charged gas around said endless, tubular enclosure, at circulation velocities in excess of 0.001 c;

(d) energy source means operable to energize said circulation means.

BI-ii

The present invention provides a device for generating magnetic field energy, said device comprising in combination:

(a) an endless, tubular, magnetic enclosure energizable by electric energy;

(b) a plasma enclosed within the magnetic enclosure, said plasma having an overall electrostatic charge;

(c) charge control means operable to adjust the overall electrostatic charge of said plasma;

(d) circulation means operable to circulate at least some of said plasma around the endless, magnetic enclosure at circulation velocities in excess of 0.001 c, said circulation means being energizable by electric energy;

(e) energy source means operable to energize said circulation means.

BII

An apparatus for converting fusion energy into magnetic field energy, said apparatus comprising in combination:

(a) a first magnetic enclosure for containing a fusion plasma, said first magnetic enclosure being energizable by electric energy;

(b) a fusion plasma enclosed within said first magnetic enclosure; said fusion plasma being energized by a fusion reaction occurring within said first magnetic enclosure;

(c) energy conversion means operable to convert the energy of said fusion plasma into electric energy, some of said electric energy being used for energizing said first magnetic enclosure;

(d) a second, endless, tubular enclosure;

(e) a charged gas enclosed within the second, endless, tubular enclosure, said charged gas having an overall electrostatic charge;

(f) circulation means operable to circulate at least some of said charged gas around said second, endless, tubular enclosure, said circulation means being energizable by some of said electric energy produced by said energy conversion means.

BIII

The present invention provides an apparatus for converting fusion energy into magnetic field energy, said apparatus comprising in combination:

(a) a first, magnetic enclosure for containing a fusion plasma, said first, magnetic enclosure being energizable by electric energy;

(b) a fusion plasma enclosed within said first magnetic enclosure, said fusion plasma being energized by a fusion reaction occurring within said first magnetic enclosure;

(c) energy conversion means operable to convert the energy of said fusion plasma into electric energy, some of said electric energy being used for energizing said first, magnetic enclosure;

(d) a second, endless, tubular, magnetic enclosure energizable by some of said electric energy;

(e) a second plasma enclosed within the second, magnetic enclosure, said second plasma having an overall electrostatic charge;

(f) charge control means operable to adjust the overall electrostatic charge of said second plasma;

(g) circulation means operable to circulate at least some of said second plasma around the second, endless magnetic enclosure, said circulation means being energizable by some of said electric energy produced by said energy conversion means.

BIV

The present invention provides a method for converting fusion energy into magnetic field energy, said method being characterized by:

(a) enclosing and maintaining a plasma within a first magnetic enclosure energizable by electric energy;

(b) initiating a controlled fusion reaction within said first magnetic enclosure by introducing a fusion fuel into said plasma;

(c) converting at least some of the fusion energy from the fusion reaction into electric energy;

(d) utilizing some of said electric energy to energize said first magnetic enclosure;

(e) enclosing and maintaining a charged gas having ions of at least one polarity within a second endless, tubular enclosure, said charged gas having an overall electrostatic charge;

(f) utilizing some of said electric energy to circulate at least some of the charged gas around the second, endless, tubular magnetic enclosure;

(g) altering the ratio of negative ions to positive ions within the second enclosure;

(h) utilizing some of said electric energy to energize the second, magnetic enclosure.

BV

The present invention provides a method for converting fusion energy into magnetic field energy, said method being characterized by:

(a) enclosing and maintaining a plasma within a first magnetic enclosure energizable by electric energy;

(b) initiating a controlled fusion reaction within said first magnetic enclosure by introducing a fusion fuel into said plasma;

(c) converting at least some of the fusion energy from the fusion reaction into electric energy;

(d) utilizing some of said electric energy to energize said first magnetic enclosure;

(e) introducing ions of one polarity into a second, endless tubular enclosure;

(f) utilizing some of said electric energy to circulate said ions around the second endless enclosure.

BVI

Method:

The present invention provides the method of converting fusion energy into magnetic field energy, said method comprising the steps of:

(a) enclosing and maintaining a charged plasma within an endless, tubular, magnetic enclosure, said charged plasma having an overall electrostatic charge;

(b) initiating a controlled fusion reaction within the magnetic enclosure by introducing a fusion fuel into said plasma;

(c) extracting at least some of the fusion energy from the fusion reaction and converting the extracted fusion energy into electrical energy;

(d) utilizing at least some of said electrical energy to circulate ions of the plasma around the endless, tubular, magnetic enclosure.

Apparatus:

The present invention provides an apparatus for generating a magnetic field, said apparatus comprising in combination:

(a) magnetic enclosure means for containing a plasma, said magnetic enclosure means having the shape of a hollow, endless, tube and being energizable by electric energy;

(b) a charged fusion plasma enclosed within said magnetic enclosure means, said charged fusion plasma having an overall electrostatic charge.

(c) energy conversion means for converting the energy of the fusion plasma into electric energy, some of said electric energy being used for energizing the magnetic enclosure means;

(d) circulation means for causing circulation of the fusion plasma around the endless, magnetic enclosure, said circulation means being energizable by the electric energy produced by said energy conversion means;

whereby the circulatory motion of the charged fusion plasma serves to produce a directed magnetic field.

Magnetic Field Drive Embodiments

CI

The present invention provides propulsion means for a space vehicle, said propulsion means comprising in combination:

(a) an endless, tubular enclosure;

(b) a charged gas enclosed within the endless, tubular enclosure, said charged gas having an overall electrostatic charge;

(c) circulation means operable to circulate at least some of said charged gas around said endless, tubular enclosure at circulation velocities which are sufficiently high to produce a sufficiently strong magnetic field to impart mobility to said space vehicle by interaction of said strong magnetic field with the geomagnetic field;

(d) energy source means operable to energize said circulation means.

CII

The present invention provides propulsion means for a space vehicle, said propulsion means comprising in combination:

(a) an endless, tubular, magnetic enclosure energizable by electric energy;

(b) a plasma enclosed within the magnetic enclosure, said plasma having an overall electrostatic charge;

(c) charge control means operable to adjust the overall electrostatic charge of said plasma;

(d) circulation means operable to circulate at least some of said plasma around the endless, magnetic enclosure at circulation velocities which are sufficiently high to generate a sufficiently strong magnetic field to impart mobility to said space vehicle by interaction of said strong magnetic field with the geomagnetic field;

(e) energy source means operable to energize said circulation means.

## Ion Emitter Embodiments

DI

The present invention provides an apparatus operable to emit ions, said apparatus comprising in combination:

(a) an endless, tubular enclosure;

(b) a charged gas enclosed within the endless, tubular enclosure, said charged gas having an overall electrostatic charge;

(c) circulation means operable to circulate at least some of said charged gas around said endless, tubular enclosure;

(d) emission means operable to permit the controlled, directed, emission of circulating ions of said charged gas out of the endless, tubular enclosure.

DII

The present invention provides an apparatus operable to emit ions, said apparatus comprising in combination:

(a) an endless, tubular, magnetic enclosure energizable by electric energy;

(b) a plasma enclosed within the magnetic enclosure, said plasma having an overall electrostatic charge;

(c) charge control means operable to adjust the overall electrostatic charge of said plasma;

(d) circulation means operable to circulate at least some of said plasma round the endless, magnetic enclosure, said circulation means being energizable by electric energy;

(e) means operable to permit the controlled, directed emission of ions of said circulating plasma out of the endless, tubular enclosure.

DIII

The present invention provides an apparatus operable to emit ions, said apparatus comprising in combination:

(a) magnetic enclosure means for containing a plasma, said magnetic enclosure means having the shape of a hollow, endless tube and being energizable by electric energy;

(b) a fusion plasma enclosed within said magnetic enclosure means;

(c) energy conversion means for converting the energy of the fusion plasma into electric energy, some of the electric energy being used for energizing the magnetic enclosure means;

(d) circulation means for causing circulation of the fusion plasma around the endless, magnetic enclosure, said circulation means being energizable by the electric energy produced by said energy conversion means;

(e) means operable to permit the controlled, directed emission of ions of the circulating fusion plasma out of the magnetic enclosure means.

Detailed Description

For a better understanding of the embodiments of the present invention which have been broadly disclosed hereinabove, reference may be had to the following detailed description, taken in conjunction with the accompanying drawings, in which:

Figure 1 shows a schematic top view of ionomagnet embodiment AI in accordance with the present invention;

Figure 2 shows a schematic cross-section along line II-II of Figure 1;

Figure 3 shows a schematic top view of ionomagnet embodiment AI showing an illustrative electromagnetic version of the circulation means;

Figure 4 shows a cross-section along line A-A of Figure 3;

Figure 5 shows an enlarged view of a cross-section along line B-B of Figure 3;

Figure 6 shows a schematic plan elevation of magnetic field energy converter embodiment BI-i in accordance with the present invention;

Figure 7 shows a schematic plan elevation of magnetic field energy converter embodiment BVI in accordance with the present invention;

Figure 8 shows a schematic plan elevation of magnetic field energy converter embodiment BII in accordance with the present invention;

Figure 9a shows a schematic view of the earth and propulsion means in accordance with magnetic field drive embodiment CI of this invention;

Figure 9b shows two permanent magnets and their magnetic interaction forces, by analogy with Figure 9a;

Figure 10 shows a schematic top view of ion emitter embodiment DI showing an illustrative version of both the circulation means and the means operable to permit the controlled, directed emission of ions;

Figure 11 shows a schematic view of a structural combination of three ionomagnet-ion emitters, each of which has been rotated out of its normal operating orientation by $90^0$ about its diameter line for illustrative clarity;

Figure 12 shows a schematic electrical wiring diagram for the electromagnetic circulation means illustrated in Figure 3;

Figure 13 shows a schematic top view of ionomagnet embodiment AI showing an illustrative electrostatic version of the circulation means.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Ionomagnet Embodiments

AI

As schematically shown in Figures 1 and 2 of the drawings, the ionomagnet of the present invention includes an endless, tubular enclosure in the form of a hollow torus 1, a charged gas 2 which is enclosed within the toroidal containment volume 4 defined by the walls of torus 1, and circulation means 3 which are operable to circulate the enclosed charged gas 2 circumferentially about the axis of torus 1 at circulation velocities in excess of 0.001c (c = speed of light).

In Figures 1 and 2, the charged gas 2 is shown to be composed only of positive ions (e.g. protons) and thus has an overall positive charge; however, it shall be understood that any charged gas, as defined hereinbefore, may be employed. In fact, it is desirable to employ only electrons due to their advantageously low mass density, circulation of ions of charged gas 2 in the direction of the arrows of Figure 1 produces a magnetic field whose magnetic flux lines have the directions indicated by the arrows of Figure 2. It will be apparent that the magnetic field intensity $\vec{H}$ is a function of the magnitude of the total charge Q on the charged gas 2, the circulation frequency f of the ions around the torus, and the radius R of the torus ($H \propto \frac{Qf}{R}$). Accordingly, the magnitude of the magnetic field intensity H is a function of the average charge density $\rho$ (averaged over containment volume 4), the radius r of a torus cross-section, the circulation velocity v of the ions around the torus, and the radius R of the torus itself (i.e. $H \propto \frac{\rho r^2 v}{R}$). Prescription of these four parameters ($r$, $R$, $\rho$, $v$) is clearly of primary importance in determining the intensity H of the magnetic field produced by ionomagnets of the present invention.

Of these four parameters, r and R may be classified as design parameters which are permanently characteristic of a particular torus. For maximum field intensity H, and assuming that the radio r/R is always equal to or greater than some constant value (but $^r/R \leqslant 1$), it is obviously desirable to maximize both r and R; in other words, the torus should preferably resemble as large and as fat, a hollow donut as is practicable.

The remaining two parameters, $\rho$ and v, may be classified as operating parameters which may be regulated for the purpose of controllably varying the magnetic field intensity both before and during operation of the ionomagnet. Moreover, in order to produce magnetic fields of significant magnitude, it is preferable that $\rho$ have a value of at least $10^{-6}$ coulombs/m$^3$, while v should have a value of at least 0.001c (i.e. $3 \times 10^5$ m/sec) and preferably in excess of 0.5c.

It will be apparent from the above discussion and from the expressions which follow, that the magnitude of both Q and $\rho$ should be as large as possible. In the context of this invention, charge densities $\rho$ of at least $10^{-6}$ coulombs/$m^3$ are desirable. In fact it has been determined that $\rho$ should be $10^{-2}$ coulombs/$m^3$ or greater for more advantageous application of the novel ionomagnet to a magnetic propulsion drive in a manner to be described hereinafter.

For most useful applications, it is contemplated that rather large ionomagnets will be used. In general, the toroidal radius R will be greater than 5 cm. Moreover, ionomagnets having an R of several metres or more will find particular application as magnetic propulsion drives for atmospheric and space vehicles by virtue of their greater charge enclosing capacity.

If suitable simplifying assumptions are accepted for ease of calculation, then the maximum field intensity $\vec{H}(r, R, \rho, v)$ (at the centre of the torus) may be expressed by

$$\left|\vec{H}(r,R,\rho,v)\right| = \frac{\pi}{5}\frac{I}{R} = \frac{\pi}{10}\cdot\frac{\rho r^2 v}{R} \qquad \ldots(1)$$

wherein I is the "ion current" in amperes. For example, for a torus having R equal to 2 metres and r equal to 1 metre, the expression becomes

$$\left|\vec{H}(1,2,\rho,v)\right| = \frac{\pi}{20}\cdot\rho v \qquad \ldots(2)$$

If the torus is filled with ions (e.g. protons) until a charge density of 1 coulomb/$m^3$ is attained, and if the charged gas of ions is accelerated to a circumferential circulation velocity of 0.67c, then the magnetic field intensity $\left|\vec{H}(1,2,1,.67c)\right|$ would be $\pi \times 10^7$ oersteds or about 30 million oersteds.

Fields of this magnitude have heretofore been unattainable due to the resistivity of conventional conducting materials to the passage of the requisite high magnitude currents (the ion current of this example was about $10^8$ amperes). Since the ions of charged gas 2 travel through a substantially empty toroidal containment volume 4, they do not encounter the conventional resistivity to their circulating motion. It

is therefore preferable that the torus be substantially evacuated before filling it with ions and that the charged gas contain only single polarity ions in order that resistance to the flow of ions by neutral particles and by oppositely charged ions be minimized.

Filling of the torus 1 with a charged gas 2 of ions may be carried out by any suitable charge control means (not shown). For this purpose, a conventional linear accelerator could be used as an injector to inject ions (e.g. protons or electrons) through an entry port into the preferably evacuated toroidal containment volume 4 in a continuous fashion until a desired charge density is attained. Alternatively, a high energy electron gun, such as that devised by B. Schumacher and outlined on page 48 of the June 7, 1968 issue of Time magazine, may be employed. In either case, the injection energies of the ions should be sufficiently high to overcome the electrostatic repulsion of the like-charge particles which have already been injected into the toroidal containment volume 4; accordingly, the injector (e.g. linear accelerator) should preferably be capable of operating over a continuous range of sufficiently high injection energies (e.g. in excess of 1 MeV). To guard against damage to the torus walls by ions having excessive injection energies, it is also preferable that the entry port be directed tangential to the centreline of the toroidal containment volume 4.

The filling of torus 1 with ions may also be accomplished without using an injector. For example, an electrically neutral hydrogen gas may be introduced into the preferably evacuated torus. The hydrogen gas may then be locally ionized by repetitive high voltage discharge between two inserted tungsten electrodes. Ions of one polarity (e.g. electrons) may then be drawn off through a port located near the tungsten electrodes to an electrode of opposite polarity (e.g. positive). By continuous ionization and simultaneously depleting ions of one polarity (e.g. electrons), a charged gas composed almost entirely of opposite polarity ions (e.g. protons) may be attained.

Such ion depletion means, comprising an electrode in spatial communication (e.g. through a hollow passage) with the interior of the torus, may be used as charge control means operable to adjust both the overall electrostatic charge of the charged gas and the quantity of charged gas within the enclosure. Accordingly, such ion depletion means may be employed in supplementary fashion after the torus has been filled with ions (e.g. by an injector) for regulating the charge density during operation of the ionomagnet.

Removal of undesirable ions and electrically neutral gas particles may be effected by means of a vacuum pump in communication with the toroidal volume 4 through an ion-repelling evacuating port. For this purpose, the evacuating port (not shown) may comprise an annular conducting ring connected to a high voltage electrode of the same polarity as the desired ions of the enclosed charged gas 2. The said ring will thus repel the enclosed ions from the evacuating port while permitting removal of neutral and oppositely charged ions.

In the context of this disclosure, it will be understood that as high a vacuum as possible is desirable prior to filling the torus with ions, since any residual molecules will cause an undesirable viscous drag on the orbital motion of the charged gas ions.

The tubular, endless enclosure of this invention, which is illustratively represented by torus 1 in Figures 1 and 2, may preferably include both a physical toroidal vessel and means for generating a toroidal confining magnetic or electrostatic field within the physical toroidal vessel.

While any operable prior art toroidal magnetic field generator may be employed to assist in confining the charged gas 2, the preferred field generator means are those disclosed in: United States Patent No. 3,143,477, issued on August 4, 1964 to Jean-Michel Dolique; and United States Patent No. 3,156,621, issued on November 10, 1964 to V. Josephson.

A toroidal confining electrostatic field may be produced by merely maintaining the wall of the hollow toroidal vessel at an

electrical potential of the same polarity as that of the enclosed ions, whereby the ions will be repelled from the interior surface of the torus wall. For this purpose, the innermost surface of the torus wall should be electrically conducting and may be electrically connected to a high voltage electrode of the same polarity as that of charged gas ions.

In the preferred ionomagnet embodiment illustrated in Figures 3, 4, 5 and 12, no field generator is used for the sole purpose of confining the charged gas. While the circulation means of this embodiment does, in fact, constrict the charged gas to a substantially annular configuration by the action of magnetic fields, its primary function is to cause circulation of the charged gas ions around the torus. Accordingly, the "tubular, endless enclosure" of this embodiment shall encompass only the physical toroidal vessel or torus 1.

To permit manipulation of the charged gas by magnetic fields produced by the circulation means, the wall of torus 1 should be magnetically permeable. To prevent leakage of charge from the enclosed ions, the torus wall should be electrically insulated. To permit evacuation of the torus before filling with ions, the torus wall should be gas impermeable. Moreover, since a pair of diametrically (relative to the torus) opposed circulating ions repel each other magnetically, and in view of the mutual electrostatic repulsion of the enclosed like-polarity ions, the torus wall should be structurally strong (high tensile strength). Also, even though some of the ions will contact and adhere to the wall of the torus, thereby electrostatically repelling the rest of the ions from contacting the interior surface of the torus wall, some "frictional" heating may be in evidence during rapid circulation of the charged gas; accordingly, it is preferable that the torus wall have a high melting point or be provided with suitable cooling means.

Figure 5 shows one choice for a lateral cross-section of torus 1 wherein the wall is composed of three layers 5, 6 and 7.

The outermost layer 5 is composed of an electrically insulating material such as plastic or ceramic. The intermediate layer 6 is a high tensile strength, magnetically permeable, and gas impermeable material such as brass or tungsten. The innermost layer 7 is a heat-resistant material such as ceramic or asbestos.

However, one disadvantage of such a wall structure is that a brass or tungsten layer 6 has free conduction electrons. Accordingly, during operation of the ionomagnet, the circulation means may cause excessive circulation of these conduction within layer 6 (e.g. tungsten), thereby causing undesirable heating of the tungsten layer. Although this heating effect may be overcome by suitable coding means such as cooling fins (with interchange of the positions of layers 5 and 6) or a refrigerating unit, it is preferable to avoid such complications by a different choice of a material for layer 6.

Accordingly it is preferred that layers 5 and 6 be replaced by a single layer of strong, magnetically permeable, electrically insulating material such as ceramic, glass or the like. The thickness of this single layer should be gauged having regard to both the mechanical strength requirements of the proposed ionomagnet operation parameters, and to the dielectric breakdown voltage strength characteristic of the particular choice of insulating materials (to prevent arcing or leakage of charge from the enclosed ions through the insulator wall). In order to further increase the dielectric breakdown voltage strength without substantial thickening of the insulating wall, it is advantageous to apply an outermost coating of Bati $O_3$ (maintained at 120 to 130$^{0}$C), or other high breakdown strength substance.

After a hollow torus having an electrically insulating wall structure as outlined above is filled with a high charge density of ions by a linear accelerator or the like, these ions remain permanently confined within the torus. Accordingly, the ion-filled torus may be stored until it is to be used, in conjunction with suitable circulation means, to produce magnetic fields.

The circulation means 3 may utilize either electromagnetic or electrostatic fields to accelerate the enclosed charged gas 2 to high circulation velocities.

Figures 3, 4 and 12, illustrate a preferred electromagnetic circulation means. This circulation means comprises a plurality of electromagnetic coil assemblies and selectively spaced along the circumference of the torus 1. Each of the coil assemblies comprises at least three magnetic coils 9 (four coils are shown in Figure 4) which are radially spaced about, and having their coil axes intersecting substantially centrally of a cross-section through the torus 1. At least three of the coils 9 in each coil assembly have magnetic poles of like polarity facing inwardly toward the centre of the torus cross-section.

When current is passed through the coils 9 of one of the "star-shaped" coil assemblies 8 the resulting field acts in the manner of a magnetic mirror to constrict or "pinch" the charged gas 2 in the vicinity of the torus cross-section encircled by that coil assembly. The degree of pinching is proportional to the current through the coils 9.

In order to cause circulation of charged gas 2, the power supply to the coil assemblies 8 should be three-phase (polyphase in general). Accordingly, the total number of coil assemblies or "stars" 8 should be a multiple of three, and these stars are cyclically and sequentially connected to successive phases via separate wires of a three-phase alternating current supply system, as schematically indicated for two such successive stars 8 in Figure 12. As shown, the basic power supply unit 10 may preferably be followed by a transformer 11, which in turn supplies a rectifier 12 and an inverter 13. Rectifier 12, with an interposed control rheostat 14, operable to control the supply of direct current to the coil stars 8. The inverter 13 should also include means for regulating the frequency and amplitude of the three-phase current.

The effect of this D.C. current with superposed 3-phase component is to generate an overall magnetic field which, in addition to its constant field pinch component, has for n coil stars 8 a total of $^{n}/3$ "pinch" zones circulating around the torus at a circulation velocity which is proportional to the frequency of the superimposed alternating 3-phase current component. Each pinch zone tends to displace ions circumferentially toward regions of lower instantaneous magnetic field strength. Since these "pinch" zones themselves circulate around the torus, they impart to charged gas 2 a corresponding average circulating motion around the torus 1. This circulatory action is somewhat similar to the swallowing action of the human oesaphagus. An arrangement of nine coil stars 8 according to Figure 3 generates three zones of higher ion density alternating with three pinch zones of comparatively lower ion density. It may be noted that three of the nine coil stars in Figure 3 are schematically indicated by lines 8 to avoiding cluttering this illustration.

It will be apparent that by gradually increasing the frequency of the 3-phase alternating current and thereby gradually accelerating the ions, desirably high circulation velocities may be attained.

Upon consideration, it will be apparent that the iono-magnetic field, which is produced by circulation of the charged gas, will interact with the circulation-promoting fields of the coils 9. This interaction may, under certain circumstances, produce large torques capable of distorting the coil assemblies 8 unless suitable and sturdy coil mounts are employed.

A second electromagnetic circulation means which avoids the latter difficulty will now be described without reference to illustrative drawings (because of its very simplicity). In accordance with this second arrangement, a plurality of solenoidal coils are successively and circumferentially spaced about the torus. Each solenoidal coil is simply formed by winding a conducting wire about a cross-section of the torus. In a manner akin to that outlined for the

"star" circulation means, the successive solenoidal coils should be cyclically and sequentially connected to successive phases of a poly-phase a.c. power supply. If the power supply is three phase, it will be apparent that the number of solenoidal coils should be a multiple of three. Once again, direct current should also be supplied to each of the coils to cause a static toroidal squeezing of the enclosed charged gas. The dynamic circulatory action is again provided by the polyphase supply, whose frequency should preferably be controllably variable up to frequencies of the order of $10^9$ cycles/sec, to permit attainment of advantageously high ion circulation velocities.

Another previously disclosed circulation means utilizing electromagnetic fields includes a number of circumferentially spaced solenoidal coil segments wound about the torus 1. A control wave guide is located in spaced parallel adjacency to, and in circumferentially intermittent electrical communication with, each of the solenoidal coils. To operate this device, D.C. current is passed through the solenoidal coils, to thereby generate a toroidal confining field within the torus. A wave generator connected to the control wave guide is then energized to generate a circulating wave within the waveguide. As the circulating wave passes a point which is connected to one of the solenoidal coils, its H-component induces a transient variation or pinch of the local field within that coil segment. In this manner, the control wave guide generates a number of circulating pinch zones which, once again, cause circumferential ion circulation. By increasing the microwave frequency, high ion circulation velocities may be attained.

A suitable electrostatic field circulation means may be provided (see Fig. 13) by combining a number of annular conducting rings 15 to form the innermost toroidal layer of the torus 1 with a suitable outer insulating (e.g. ceramic) layer 5 of sufficient thickness to prevent arcing. Once again a Bateman-type control wave

guide 16 (microwave generator and access therefrom to waveguide are not shown) may be electrically connected to each of the conducting rings 15. A constant potential of the same polarity as that of the enclosed ions is then applied to each of the rings 15 to thereby produce a toroidal confining electrostatic field within the torus. In this electrostatic case, it is the E-component of the electromagnetic wave generated in the control wave-guide which causes transient variation in the electrostatic field produced by, and in the cross-section enclosed by, each conducting (e.g. tungsten) ring 15. It will be apparent that the e-m wave therefore generates circulating electrostatic pinch zones whose circulation velocity is proportional to the frequency of the E-component of the e-m wave. Once again, these circulating pinch zones cause circumferential circulation of the charged gas 2 about the torus.

It will be apparent that two or more of the above-outlined circulation means may be advantageously employed in combination. For example, the aforementioned "star" coil assemblies may be used to initiate the circulating ion motion up to low circulation velocities, and the electrostatic circulation means of Fig. 13 may cut in to accelerate the charged gas to the desired final velocity.

Irrespective of the particular choice of a circulating means, almost any final ion velocity (subject to the restrictions of special relativity) may be attained if the rate of circulation kinetic energy input by the circulation means exceeds the rate of energy loss of the circulating charged gas system. These energy losses may be readily grouped into (a) heating losses by kinetic interaction between ions, (b) electrostatic field losses by variations in polarization of nearby dielectrics, and (c) magnetic induction and hysteresis losses in nearby conductors and ferromagnetic materials. Since the latter two sources of energy dissipation may be minimized by appropriate choice of surroundings (e.g. air, vacuum), they may be overcome by an adequate circulation energy input, thereby permitting acceleration of the ions to any desired final velocity.

AII

As an alternative method, a plasma may first be generated and confined in any suitable endless, tubular, magnetic enclosure in accordance with the prior art (e.g. U.S. Patent No. 3,156,621 by V. Josephson). While maintaining the plasma, ions of one polarity are depleted. The remaining hot plasma has an overall electrostatic charge and may be circulated about the torus to produce a magnetic field, while simultaneously magnetically containing the hot plasma to prevent contact with the torus walls, the innermost layer of which should have a high melting point (e.g. asbestos).

However, instead of circulating the hot plasma, it is preferred that the remaining plasma, having an overall electrostatic charge, is then allowed to cool (or is artificially cooled) to below the temperature at which destructive interaction between the plasma and the enclosure walls can occur. Once the temperature has been lowered, magnetic containment per se is no longer necessary and may be terminated.

Once again, it is preferred that the physical walls of the endless enclosure be structurally strong (tensile strength), electrically insulated, magnetically permeable, and should have a high melting or combustion temperature (see Fig. 5).

Auxiliary charge control means to regulate the charge of the enclosed hot/cold charged plasma may also be provided. For this purpose, both the previously disclosed injector and ionization-depletion devices may be employed.

When a magnetic field is desired, it is only necessary to circulate the resultant charged gas of "hot" or "cold" ions by one of the circulation means expedients outlined hereinabove under AI.

The ionomagnet of this invention is readily distinguishable from structurally similar prior art devices such as the belatron since, inter alia, the novel ionomagnet (i) does not utilize axial (relative to the torus) magnetic fields to circulate the ions, and since (ii) the ionomagnet encloses a charged gas or plasma having a substantial total charge and charge density.

Magnetic Field Energy Converter Embodiments

BI-i

This embodiment provides a device for generating magnetic field energy. It includes the ionomagnet disclosed under AI in operative combination with an energy source means operable to energize the circulation means of the AI ionomagnet. Any suitable energy source means may be employed for this purpose. For example the energy source may be electrical mains or an electricity generator.

As shown in Figure 6, such an electricity generator may comprise an energy source 17 fed by a fuel supply 18 to supply energy in some form for conversion to electrical energy by suitable energy conversion means 19.

BI-ii

An alternative device for generating magnetic field energy includes the ionomagnet disclosed under AII in combination with an energy source means operable to energize the circulation means of the AII ionomagnet. Once again, a suitable energy source means may be electrical mains or an electricity generator.

BII and BV

This embodiment provides an apparatus and method for converting fusion energy into magnetic field energy. As shown in Figure 8, the novel apparatus comprises the operative combination of:

(a) a first magnetic enclosure 20 for containing and maintaining a fusion plasma 21 within which a thermonuclear fusion reaction is occurring;

(b) energy conversion means or energy converter 19 operable to convert the energy of the fusion plasma into electric energy;

(c) an ionomagnet as outlined under AI hereinabove and including a torus 1, an enclosed charged gas 2, and a circulation means 3; the circulation means 3 being energizable by some of the electric energy from the energy converter 19.

As shown, the apparatus may also include fusion fuel supply means 22 to supply fusion fuel to the fusion reaction at a controllable rate.

The first magnetic enclosure 20 may be any magnetic enclosure which is operable to contain and maintain a fusion plasma. For this purpose any operable prior art enclosure may be employed. Since most of such prior art magnetic bottles are energized by electric energy, some of the fusion energy extracted from the fusion reaction and transformed to electric energy by energy converter 19 may be diverted to magnetic enclosure 20 for this purpose.

Since most of energy produced by a fusion reaction is heat energy, it is preferable that energy converter 19 be operable for heat-to-electricity conversion. While certain obvious expedients will immediately suggest themselves to those skilled in the art, two heat-to-electricity converter types appear particularly preferable:

(a) the "aerosol-spray" heat-to-electricity converters disclosed in U.S. Patent No. 3,191,077, issued June 22, 1965 to Alvin M. Marks et al, and in U.S. Patent No. 3,297,887, issued January 10, 1967 to Alvin M. Marks;

(b) the "fluid pressure-to-electricity" conversion device disclosed in U.S. Patent No. 3,496,871, issued to Linda F. Stengel on February 24, 1970, which may be utilized either indirectly (through the action of a heat-expansible medium such as a gas), or directly (by utilizing the high pressures of the enclosed plasma).

The energy converter 19 should also include electricity-to-electricity conversion means to transform the "crude" electrical energy derived from heat-to-electricity conversion into electricity of suitable amplitude, phase, a.c./d.c., and frequency (e.g. microwaves for a control waveguide) to energize the circulation means 3 and the magnetic enclosure 20.

BIII and BIV

This embodiment provides a method and apparatus for converting fusion energy into magnetic field energy which is very similar to the apparatus outlined under BII; for brevity only the contrasting features between the BII embodiment and this (BIII) embodiment will be set forth.

Instead of an AI ionomagnet (as in BII), the apparatus of this embodiment utilizes an AII ionomagnet. As set forth under AII, the charged gas may comprise either "cold" ions or hot plasma ions. Moreover the AII ionomagnet should include charge control means to permit regulation of the enclosed charge (e.g. by altering the ratio of negative ions to positive ions).

BVI

This embodiment provides an apparatus and method for converting fusion energy into magnetic field energy. As shown in Figure 7, the apparatus of this embodiment comprises:

(a) magnetic enclosure means 20 for containing a plasma, said magnetic enclosure means 20 having the shape of a hollow, endless tube (e.g. a torus) and being energizable by electric energy;

(b) a charged fusion plasma 23 enclosed within said magnetic enclosure means 20;

(c) energy conversion means 19 for converting the energy of the fusion plasma 23 into electric energy, some of said electric energy being used for energizing the magnetic enclosure means 20;

(d) circulation means 3 for causing circulation of the charged fusion plasma 23 around the endless magnetic enclosure 20, said circulation means 3 being energizable by some of the electric energy produced by said energy conversion means 19.

In order to produce magnetic fields of significant magnitude, it is preferred that the charged fusion plasma 23 have a charge density of at least $10^{-6}$ coulombs/$m^3$ and an overall electrostatic charge of at least $10^{-6}$ coulombs.

Further, it shall be understood that the circulation means 3 and energy conversion means 19 of this embodiment are of the types outlined hereinabove under other embodiment headings.

MAGNETIC FIELD DRIVE EMBODIMENTS

CI

This embodiment provides propulsion means for a space vehicle or the like comprising the apparatus outlined hereinabove under BI-i wherein:

(a) the charged gas has an average charge density of at least $10^{-6}$ coulombs/$m^3$ and an overall electrostatic charge of at least $10^{-6}$ coulombs;

(b) the circulation means are operable to circulate at least some of the charged gas around the torus at circulation velocities which are sufficiently high to produce a sufficiently strong magnetic field to impart mobility to said space vehicle by interaction of said strong magnetic field with the geomagnetic field.

It will be apparent that the apparatus of BII, BIV, and BV may be utilized for this purpose.

Figures 9a and 9b illustrate the operation of the magnetic field drive of this embodiment. Fig. 9b shows the interaction forces between two bar magnets 24, 25 with juxtaposed like poles. The repulsion force between these bar magnets is analogous to the repulsion force F between the weak geomagnetic field 28 of the earth 26 and the strong magnetic field 29 of the ionomagnet-cum-energy source 27.

For illustrative purposes, it is of interest to carry out a sample calculation of the repulsion force F between the magnetic field H of a toroidal ionomagnet of radius R and the geomagnetic field Be. The simplified governing equation is then

$$F = Be.H.R^2$$

If H and R are chosen to be $\pi \times 10^7$ oersteds and 2 metres respectively (as calculated herein under AI), and since $B_e$ is about half a gauss (or oersted in free space), then the repulsion force F is approximately $2\pi \times 10^7$ newtons. This force is adequate to lift approximately $6 \times 10^6$ kilograms against the pull of gravity!

Accordingly, the ionomagnetic field drive may be used to propel a space vehicle from the surface of the earth to regions of space where other means (e.g. ion drives as per Figs. 10 and 11) may be employed in the absence of gravitational attraction. By contrast to present-day chemical fuel rockets, the ionomagnetic field drive vehicle of this embodiment operates in a reusable manner at controllably low accelerations.

Further, as shown in Fig. 11, it is advantageous to link three ionomagnets together at the corners of a triangle by means of structural members for stability and to permit spatial orientation of the vehicle.

It will be apparent that the ionomagnetic field drive can also be utilized for atmospheric and surface travel with the aid of an auxiliary forward propulsion drive. For this application the ionomagnet serves the lift/support function of aeroplane wings and automobile tires and further permits vertical lift off, thus obviating costly landing strips and highways.

In a further application of the novel ionomagnetic drive, three or more ionomagnets may be mounted on the earth's surface to form a "landing grid". An ionomagnetic drive vehicle may then propel itself by repulsion of the vehicle's ionomagnetic field against that of the "landing grid".

CII

This embodiment utilizes the apparatus outlined under any of BI-ii, BIII or BVI, but otherwise operates in the manner set forth under heading CI.

## ION EMITTER EMBODIMENTS

DI

This embodiment provides an apparatus operable to emit ions comprising the ionomagnet described under AI in combination with emission means operable to permit the controlled, directed emission of circulating ions of the charged gas out of the endless tubular enclosure.

As shown in Fig. 10, the emission means preferably comprises a tubular member 30 in tangential communication with a torus 1. Tubular member 30 may preferably be surrounded by "star" coil assemblies 8a (according to Drabier et al) along the length of the member to guide the tangential emission of ions through tubular member 30 and to control their flow by applying a "magnetic mirror" effect by means of the "star" assembly 8a nearest the torus 1.

This embodiment has obvious application for research and as an "ion space drive" (see Fig. 11).

DII

This embodiment utilizes the ionomagnet of AII, but otherwise operates as outlined under DI.

DIII

This embodiment utilizes the ionomagnet-cum-energy source of BVI, but otherwise uses emission means as outlined under DI.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A method for producing a magnetic field, characterized by the steps of:

   (a) enclosing a charged gas within an endless tubular enclosure, said charged gas having an overall electrostatic charge,

   (b) circulating at least some of the enclosed charged gas at circulation velocities in excess of 0.001c.

2. A method according to Claim 1, wherein the charged gas has an average charge density of at least $10^{-6}$ coulombs/$m^3$, and wherein said overall electrostatic charge is at least $10^{-6}$ coulombs.

3. A method according to Claim 2 wherein the temperature of the enclosure is maintained below a preselected temperature characteristic of the material composition of the walls of the enclosure.

4. An apparatus for producing a magnetic field comprising in combination:

   (a) an endless, tubular enclosure;

   (b) a charged gas enclosed within the endless tubular enclosure, said charged gas having an overall electrostatic charge;

   (c) circulation means operable to circulate at least some of said charged gas around said endless tubular enclosure, at circulation velocities in excess of 0.001c.

5. An apparatus according to Claim 4, wherein the charged gas has an average charge density of at least $10^{-6}$ coulombs/$m^3$, and wherein said overall electrostatic charge is at least $10^{-6}$ coulombs.

6. An apparatus according to Claim 5, the walls of said endless tubular enclosure being electrically insulated, gas impermeable, structurally strong, and magnetically permeable.

7. An apparatus according to Claim 5, further including cooling means for cooling said endless tubular enclosure.

8. An apparatus according to Claim 5, further including charge control means operable to adjust the overall electrostatic charge of the charged gas.

9. An apparatus according to Claim 8, said charge control means comprising a high energy electron gun.

10. An apparatus according to Claim 8, said charge control means comprising a linear ion accelerator operable at ion injection energies in excess of 1 MeV.

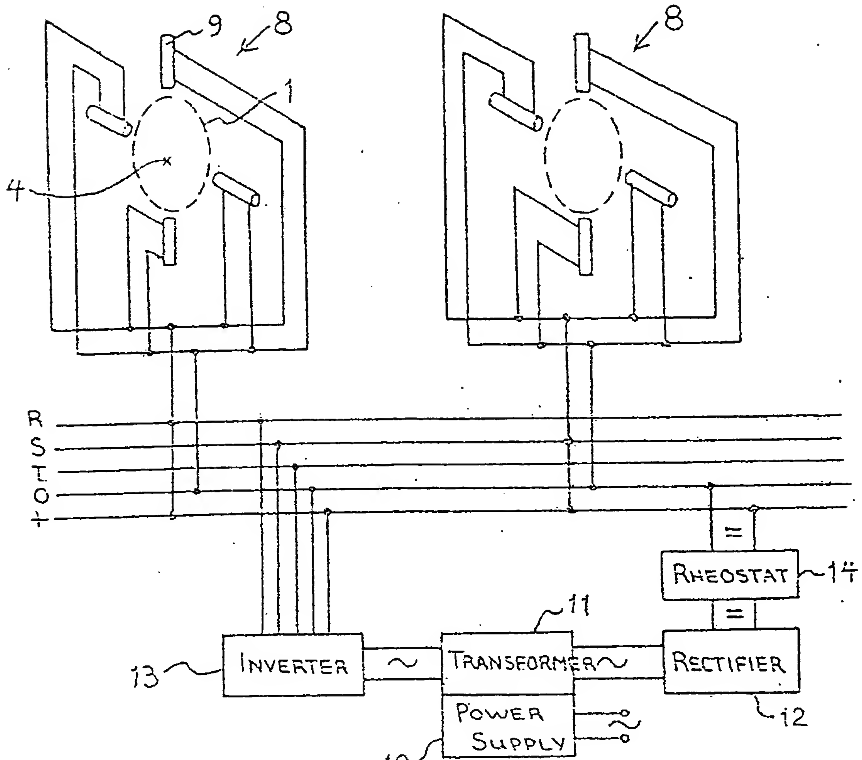
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FIG 12

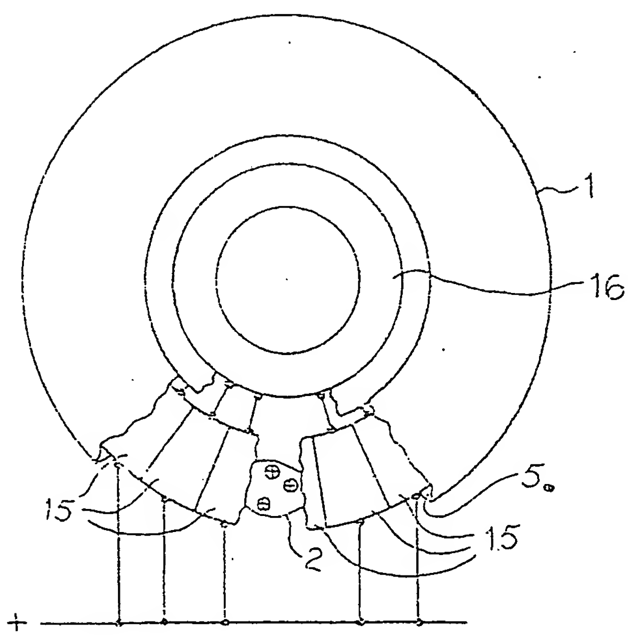
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FIG 13

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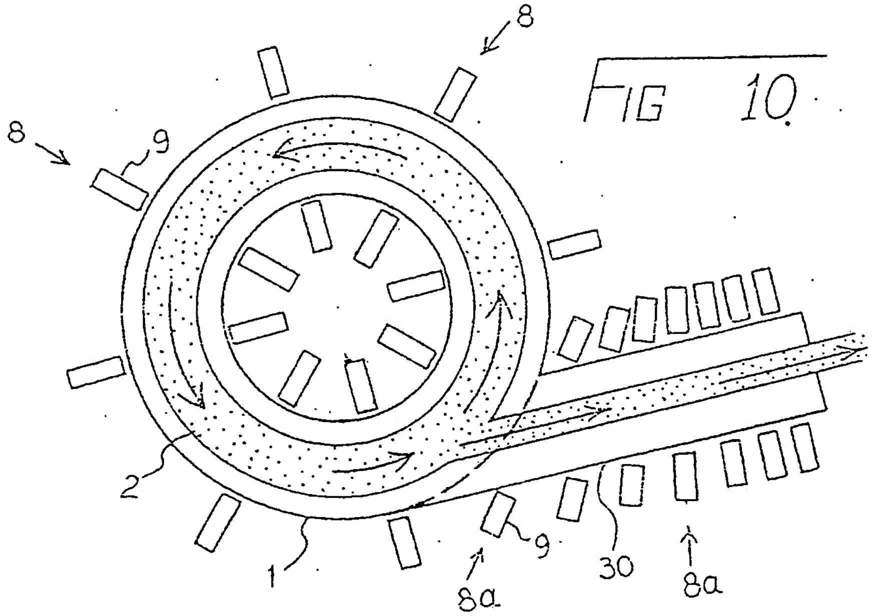



FIG 10.

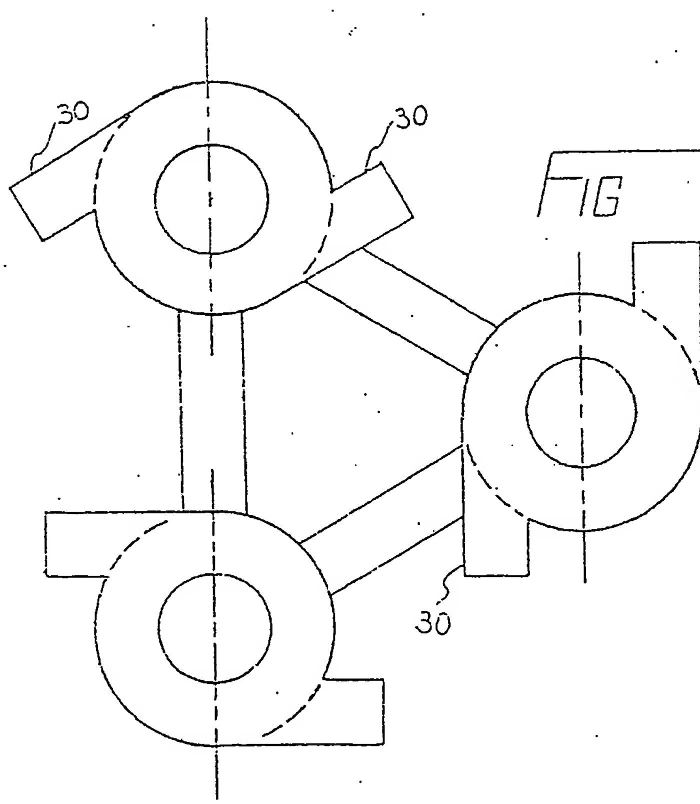
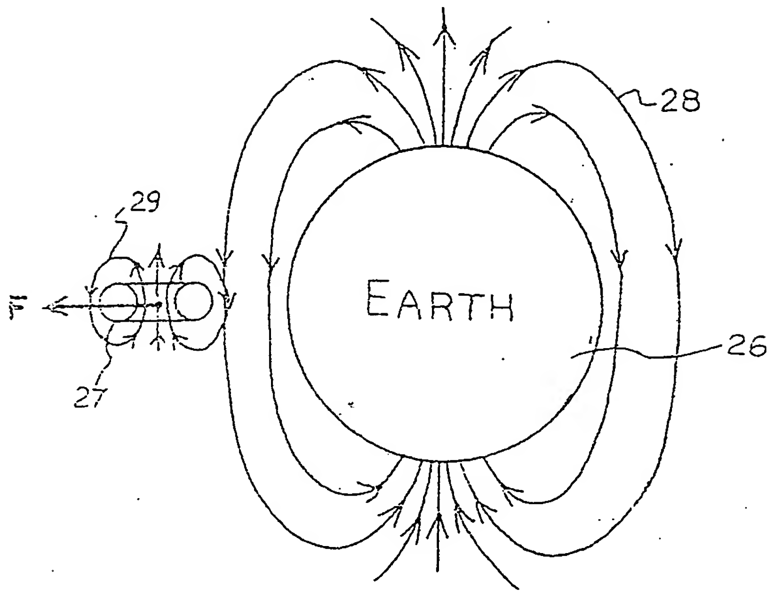



FIG 11

FIG 9a



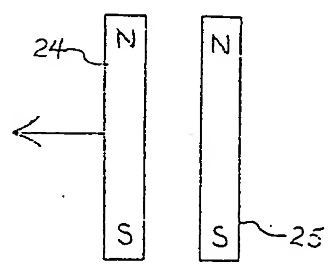




FIG 9b

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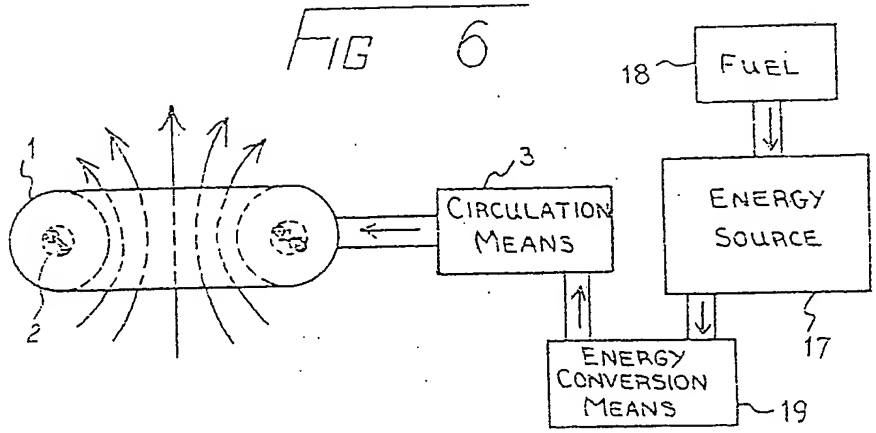
FIG 6



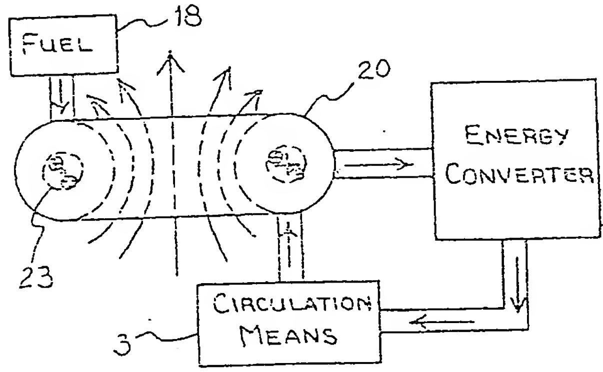




FIG 7

FIG 8

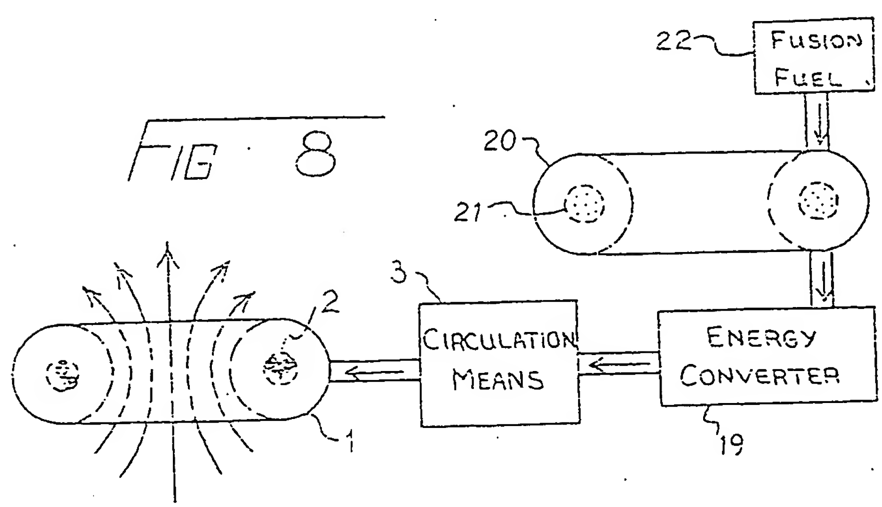
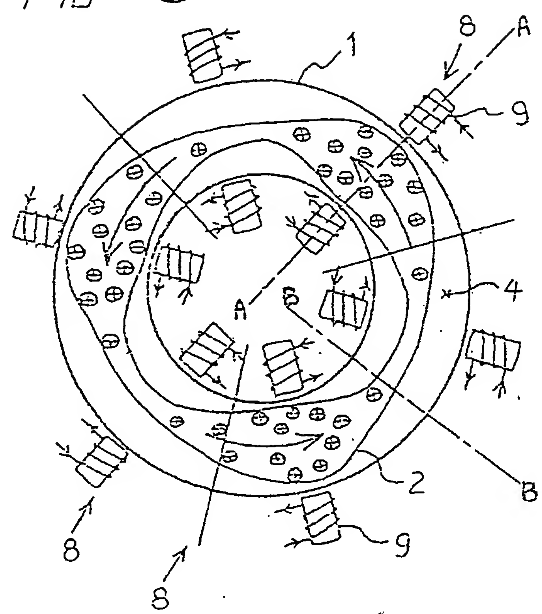


FIG 3



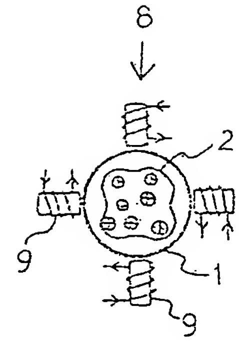




FIG 4

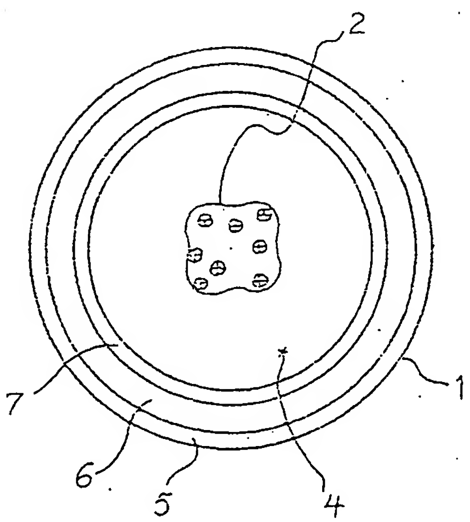



FIG 5

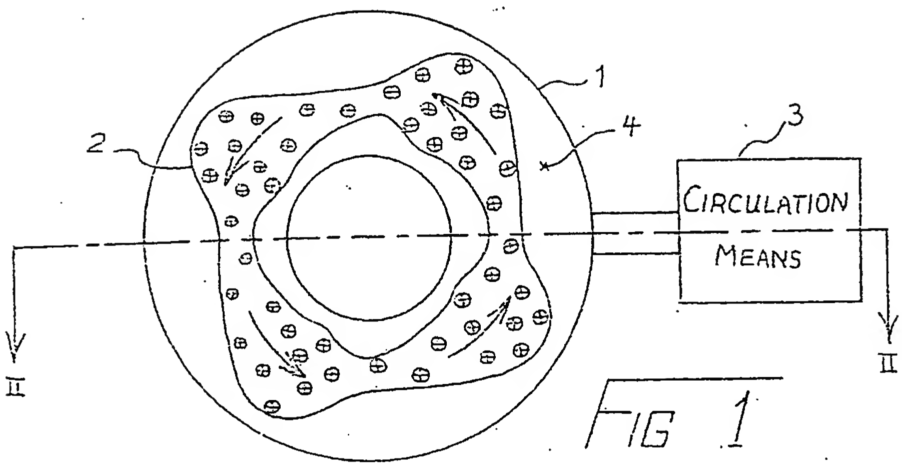



FIG 1

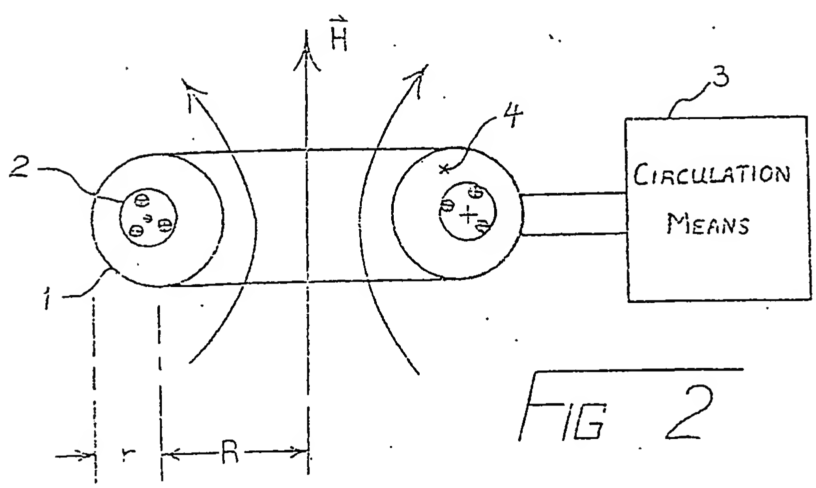



FIG 2